Thus, by subtraction

$$\begin{aligned}&\lambda C(y_1,\Lambda\ ,y_n,w_1,\Lambda\ ,w_m)-\lambda C(0,y_2,\Lambda\ ,y_n,w_1,\Lambda\ ,w_m)\\&=C(y_1,\Lambda\ ,y_n,\lambda w_1,\Lambda\ ,\lambda w_m)-C(0,y_2,\Lambda\ ,y_n,\lambda w_1,\Lambda\ ,\lambda w_m)\end{aligned}$$

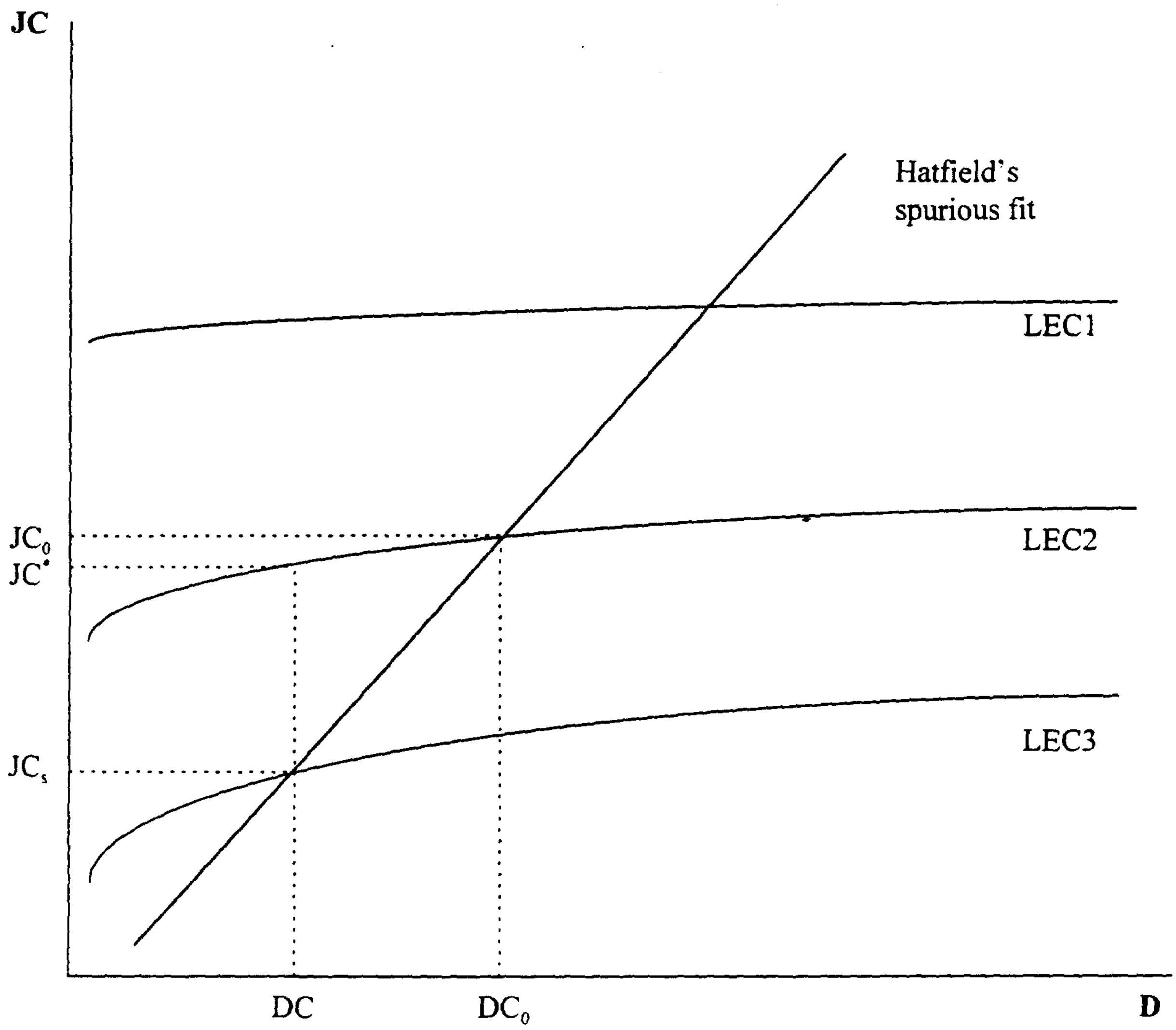
or

$$\lambda TSLRIC(y_1,\Lambda\ ,y_n,w_1,\Lambda\ ,w_m)=TSLRIC(y_1,\Lambda\ ,y_n,\lambda w_1,\Lambda\ ,\lambda w_m).$$

Which says, in words, that proportionally increasing all input prices will increase TS/TELRICs by the same proportion.

Section B Graphical illustration of Fallacy of Division

Graphically, the error and its consequences can be clearly seen. Referring to the graph below let LEC1 be the graph of the true relationship between the direct costs (DC) of LEC1 and its joint costs (JC). Define LEC2 and LEC3 analogously. The three points where the straight line labeled Hatfield's spurious regression intersect the lines LEC1, LEC2, and LEC3 correspond to the observed values of joint and direct costs observed for each firm. Hatfield's regression runs a line through these three points. Hatfield then uses this relationship to predict the avoided joint costs for a particular firm. Here we use LEC2 as an illustration. If DC falls from DC0 to DC*, the joint costs for LEC2 fall from JC_0 to JC* -- moving along the true relationship LEC2 from point A to B. Hatfield would predict that JC would fall from JC_0 to JCs, that is, moving from A to C. So Hatfield's model will far over predict the avoided joint cost.


JC
Hatfield's spurious fit
LEC1
JC_0
JC^*
LEC2
LEC3
JC_s
DC
DC_0
D

Section C Hatfield's Formulation Has Incredible Implications

In this part of the appendix, we show that the only industries that Hatfield's formulation can be applied are those where the stand alone costs are volume insensitive. For purposes of demonstration we show this is true for the first service, it can be shown to be true for all services.

$TSLRIC_i(y_1,\ldots,y_n) = C(y_1,\ldots,y_n) - C(y_1,\ldots,y_{i-1},0,y_{i+1},\ldots,y_n)$

Direct cost can be defined

$$DC = \sum_{i=1}^{I} TSLRIC_i$$

Joint cost can be defined as

$$\begin{aligned} JC &= C - DC \\ &= C - \sum_{i=1}^{I} TSLRIC_i \end{aligned}$$

Hatfield model supposes that $JC = a + b \times DC$. This may be written as

$$C - \sum_{i=1}^{I} TSLRIC_i = a + b \times \sum_{i=1}^{I} TSLRIC_i .$$

The following algebra shows that if this is true then the standalone costs of producing services or elements is totally volume insensitive. Such an assertion is on its face certainly incorrect.

Lemma:

If $C - \sum_{i=1}^{I} TSLRIC_i = a + b \times \sum_{i=1}^{I} TSLRIC_i$ then for each service or element, i, the standalone cost of production is volume insensitive.

Proof:

$$
\begin{aligned}
C &= a + (b+1) \times \sum_{i=1}^{n} \mathrm{TSLRIC}_i \\
&= a + (b+1) \\
&\quad \times [C(y_1, \ldots, y_n) - C(0, y_2, \ldots, y_n) \\
&\quad + C(y_1, \ldots, y_n) - C(y_1, 0, y_3, \ldots, y_n) \\
&\quad + C(y_1, \ldots, y_n) - C(y_1, \ldots, y_{i-1}, 0, y_{i+1}, \ldots, y_n) \\
&\quad \mathrm{M} \\
&\quad + C(y_1, \ldots, y_n) - C(y_1, \ldots, y_{n-1}, 0)]
\end{aligned}
$$

$$
\begin{aligned}
C(y_1, \ldots, y_n) &= a + (b+1) \times n \times C(y_1, \ldots, y_n) \\
&\quad -(b+1) \times [C(0, y_2, \ldots, y_n) \\
&\quad + C(y_1, 0, y_3, \ldots, y_n) \\
&\quad + C(y_1, \ldots, y_{i-1}, 0, y_{i+1}, \ldots, y_n) \\
&\quad \mathrm{M} \\
&\quad + C(y_1, \ldots, y_{n-1}, 0)]
\end{aligned}
$$

$$
\begin{aligned}
C(y_1, \ldots, y_n) &= \frac{(b+1)}{n(b+1)-1} \times [C(0, y_2, \ldots, y_n) \\
&\quad + C(y_1, 0, y_3, \ldots, y_n) \\
&\quad + C(y_1, \ldots, y_{i-1}, 0, y_{i+1}, \ldots, y_n) \\
&\quad \mathrm{M} \\
&\quad + C(y_1, \ldots, y_{n-1}, 0)] \\
&\quad - \frac{a}{n(b+1)-1}
\end{aligned}
$$

Without loss of generality, we demonstrate the result for the first service. The standalone cost of service 1 is given by $C(y_1, 0, \ldots, 0)$. We now evaluate the result above at $(y_1, 0, \ldots, 0)$.

$$C(y_1,0,\ldots,0) = \frac{(b+1)}{n(b+1)-1} \times [C(0,0,\ldots,0)$$
$$+ C(y_1,0,0,\ldots,0)$$
$$+ C(y_1,0,0,,\ldots,0)$$
$$\mathrm{M}$$
$$+ C(y_1,0,\ldots,0)]$$
$$- \frac{a}{n(b+1)-1}$$

$$C(y_1,0,\ldots,0) =$$
$$\frac{(b+1)}{n(b+1)-1} \times C(0,0,\ldots,0)$$
$$+ \frac{(b+1)(n-1)}{n(b+1)-1} C(y_1,0,0,\ldots,0)$$
$$- \frac{a}{n(b+1)-1}$$

$$C(y_1,0,\ldots,0)\left[1 - \frac{(b+1)(n-1)}{n(b+1)-1}\right] =$$
$$\frac{(b+1)}{n(b+1)-1} \times C(0,0,\ldots,0)$$
$$- \frac{a}{n(b+1)-1}$$

$$C(y_1,0,\ldots,0)\left[1 - \frac{(b+1)(n-1)}{n(b+1)-1}\right] =$$
$$\frac{(b+1)}{n(b+1)-1} \times C(0,0,\ldots,0)$$
$$- \frac{a}{n(b+1)-1}.$$

Simplifying and solving for the standalone cost gives:

$$C(y_1,0,\ldots,0) = \frac{(b+1)\big(C(0,0,\ldots,0)\big) - a}{b}.$$

Note that the right hand side of the equation does not depend on the level of service y_1. Thus the stand-alone cost of providing a service does not depend on the level of the service provided. This means the cost of a new entrant would be the same whether it proposes to serve one customer or a million. Clearly, this is not a cost relationship that is relevant to telecommunications.

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ATTACHMENT B

INDETEC International

Table of Contents

Hatfield Model 3.0 Analysis
Executive Summary

Overview

The Hatfield Model (HM) has undergone significant change between versions 2.2.2 and 3.0. These changes have affected every important characteristic the model: the model architecture, its algorithms, and the inputs to the model have all been changed yet many of the shortcomings of HM 2.2.2 remain. HM 3.0 was constructed with a complex combination of Visual Basic, Excel, and Access software. These tools are used in combination in a manner which makes the model difficult to understand. However, in the final analysis the core of the earlier version (HM 2.2.2) and its underlying problems remains intact. As a result, HM 3.0 produces unrealistically low costs comparable to those produced by its predecessor.

Reports

HM 3.0 produces results for a set of (newly defined) density zones and for wire centers. The model cannot produce costs aggregated to the levels of an entire state or collection of states, an entire telephone company operating in multiple states, or for census block groups (CBGs).

External Validity Check

Costs in the HM 3.0 are underestimated due to a variety of data errors and structural characteristics. For example, household counts do not agree with the census data claimed to be used in the model. These differences cannot be explained by any reasonable interpretation of the data such as substituting lines for households, allowing for more than one line per household. Additional data problems are evident; for example, the area served by GTE according to GTE's records does not agree with that represented in the HM 3.0 even allowing for differences in rounding or measurement methods. Such date problems are evident throughout the model.

Model Deficiencies

The Hatfield Model version 3.0 and its predecessor, version 2.2.2, both appear to be *designed* to produce unrealistically low costs. For example, on average HM 3.0 develops the Total Cost of Switched Network Elements that is only slightly higher than the costs developed in HM 2.2.2. More dramatically, the revised model produces loop lengths that are 17 times longer than in HM 2.2.2. Yet the two models produce overall costs that are astoundingly similar. It is inconceivable that such a dramatic increase in loop length combined with modest increases in switch costs would leave overall costs largely unchanged unless other aspects of the model have been manipulated to generate a preconceived result.

Perhaps the most important input value which understates costs in the HM 3.0 is the structure sharing assumption. This problem lingers from a comparable problem in HM 2.2.2. The revised model assumes that 25% of the cost of poles and 33% of the cost of trenching would be incurred by the ILEC. The net result of the change from the earlier version of the model is minor (the earlier version assumed that 33% of poles, trenching, and conduit were shared). These values are unrealistically low in both the present and future. Most often, opportunities to share are limited. For example, in most cases it is not technically or economically possible to share trenching.. Even when sharing of trenching cost is desirable, it is often impossible for two or more companies to coordinate their permits and construction plans to achieve economies of sharing. This coupled with an understatement of structure investment for both poles and conduit results in structure costs substantially lower than those which can be achieved in practice.

The model continues to underestimate, though by a lesser degree, the appropriate loop length to serve customers. While the revised model extends the length of distribution cable over that in HM 2.2.2, those longer loops are designed so poorly that the simulated network would be incapable of accommodating standard voice communications. For example, for longer loops, 19 and 22 gauge is not manufactured in the cable sizes represented in the HM. Thus, for higher density areas, more cables (and their related costs) are required in practice than is acknowledged in the HM..

Other subloop elements carry too little cost as was the case in earlier versions of the HM. Drop characteristics and associated costs continue to be understated. Network interface device (NID) costs continue to be understated.

Switch costs are still understated in HM 3.0. The cost of switching equipment continues to be suspect (documentation of input values is lacking); Switching costs are significantly lower than costs which can be attained by operating local exchange companies.

Inter-office costs are also less than those achievable in practice due, in part, to an assumption that only 33% of all interoffice structure cost is incurred by the telephone company.

Converting Investments into Annual Costs

HM 3.0 underestimates the annual cost of investments. Depreciation lives are too long, the HM uses an incorrect application of ARMIS ratios, and investment levels (not activities) are used to determine expense levels. For example, HM 3.0 proposes depreciation lives that are 5 to 6 times greater that that proposed by AT&T in a 1994 proceeding. HM 3.0 continues to use historical investments in calculating ARMIS ratios, while inconsistently using forward looking investments in its application in the model. These forward looking investments are about half the level of the their historical counterparts, which results in assigning half the appropriate expenses to investment. Additionally, there is no reasonable relationship between the loop investment level and its corresponding maintenance.

Finally, HM 3.0 makes the unsubstantiated assumption that network efficiency will improve, not by the unrealistic 30% it proposed in HM 2.2.2 but by an even greater 50%.

HM 3.0 continues to underestimate the cost of the local telephone network.

Analysis of Hatfield Model 3.0

General Observations

Hatfield Model 3.0 ("HM 3.0") is structured differently from the Hatfield Model ("HM 2.2.2.") Most importantly, HM 3.0 uses a visual basic front end and execution routine which makes it more difficult to analyze. In addition, the algorithms are now buried in multiple Excel spreadsheets with data being pulled from an Access database running behind the Visual Basic front end, tracing algorithms through the model was impossible in the time provided.

Preliminary investigation of the "HM 3.0" reveals it to make no fundamental departure from the erroneous economic approach taken in the HM 2.2.2. HM 3.0 continues the practice observed in HM 2.2.2 of understating costs due to a combination of poor economics, faulty assumptions, unrealistic input data, and the omission of relevant material. Like HM 2.2.2, HM 3.0 is result-driven, fails a variety of validity checks, and is insufficiently documented.

In General HM 3.0 fails the homogeneity test. All input prices were increased through the user interface to levels exactly 10% above the default GTE California data provided with the Model. As illustrated in the Appendix D, the Hatfield Model's Total Cost of Switched Network Elements, increased by only 7.73%.

HM 3.0 seems to be less sensitive than HM 2.2.2 to changes in user defined inputs. This would lead one to believe that the model is designed with more hard-coded inputs than HM 2.2.2. (See Appendix A for more details.)

Reporting

There have been no improvements in reporting. Reports can only be generated at the Density Zone or wire center level and only for Company /State Combination. The wire center report is useless since it is not on a per line basis. In addition, it still cannot generate CBG reports. This is problematic since the CBG is being considered as the geographic unit of funding. HM 3.0's inability to generate total state and total company (in multiple states) reports makes it unusable for those state utility commissions that are seeking a bench marking tool.

External Validity Check

The input data developed by PNR may be flawed. The data in HM 3.0 appears to be different than that in HM 2.2.2. The documentation does not address how the Donnelly database was geocoded. The geocoding process typically renders a significant number of non-assignments resulting from insufficient address information in rural area. The manner in which these misses are handled will impact the accuracy of the geocoding. Moreover, unlisted phone numbers were not used in the process.

Household counts do not match Census based numbers and are different than HM 2.2.2. The Census based CBG data has been the cornerstone of all proxy models used to date. This data is used to approximate the number of residential customers. For some reason, the HM 3.0 has switched vendors of its customer data. In so doing, there household counts and resulting line counts do not match either census data or ARMIS data. This is a major concern because these values are used to size cable, determine densities, size switches, etc.

The table in Appendix C shows the summation of Hatfield households by state. This summation was developed from the CBG data in the Access database). This is then compared to the 1995 derived household counts which is based upon the ratio of 1995 to 1990 population counts at the county level as applied to the 1990 CBG housing data. There are significant differences in the two counts. The PNR data, is supposedly, adjusted to incorporate first and second line penetration. Using the 1995 estimated household counts, we estimated what PNR has indicated as second line penetration (assuming that we have 100% first line penetration). These penetration rates do not correlate with actual data from ARMIS.

The HM 3.0 data, while an improvement over HM 2.2.2, still understates CBG Square mile areas. California CBG square mile areas from Claritas 1990 cartographic boundary areas were compared to areas appearing in the HM 3.0 GTE California default workfile, and those in the HM 2.2.2 GTE California input file. The total square mile area of all CBGs appearing in the default GTE California HM 3.0 workfile is 55,462. The Claritas data calculates a sum of 53,693 for those CBGs. The total square mile area of all CBGs appearing in the default GTE California HM 2.2.2 input file is 27,036; the corresponding figure for those CBGs is 18,397. The actual total square mile area of GTE California wire centers is 29,912. Thus, HM 3.0 overstates the GTE California service area by 85%; HM 2.2.2 understates it by 10%.

Using the areas appearing in the models, HM 3.0 assigns over twice as much area (105% more) to GTE California CBGs than does HM 2.2.2. Using Claritas areas, HM 3.0 assigns almost 3 times as much area (192% more) to GTE California CBGs than does HM 2.2.2. Again, total distribution costs are smaller in HM 3.0's GTE California default than in HM 2.2.2's, and again, there appears to be a systematic "correction" taking place which avoids cost increases. For more information please see the table in Appendix G.

HM 3.0 Continues to Misrepresent GTE Service Areas.

Maps have been attached in Appendix H containing a visual representation of differences between CBGs assigned to GTE Washington by HM 3.0 and by HM 2.2.2 to the actual GTE California wire centers. HM 3.0 assigns 428 more CBGs to GTE California than did HM 2.2.2. In Washington, 13 fewer. In Texas, 36 fewer. 3,976 California CBGs appeared in both HM 3.0 and HM 2.2.2. HM 3.0 contains 643 that do not appear in HM 2.2.2, and HM 2.2.2 contains 215 that do not appear in HM 3.0.

The HM 3.0 data also seems to consistently underestimate the distance from the Serving Central office to the centroid of the CBG. This is based on the comparison of the average distance of Hatfield to BCPM data. While BCPM may not be correct, one would not expect that for every state analyzed that Hatfield distances would be shorter. A consistent undercalculation of this sort probably arises from a miscalculation of households. For greater detail please see the analysis of CBG Hatfield Appendix C.

Modeling Deficiencies

HM 3.0 claims that its general outside plant configuration duplicates procedures followed by outside plant planning engineers. To the contrary, HM 3.0 violates planning engineer's practices, because it (1) permits loops longer than 12,000 feet (see 1994 AT&T Outside Plant Engineering Handbook); (2) places multiple gauges in the distribution; (3) places loading in the distribution.

HM 3.0 contradicts itself when assigning a percentage figure to each mixture of plant (aerial. underground, or buried). On page 27 of the documentation, HM 3.0 states that "in downtown urban areas it is frequently necessary to install cable in underground conduit systems, while rural areas may accommodate less expensive aerial or direct-buried plant." Yet the input table (page 30) assigns 85% of "downtown urban" areas plant to aerial and only 25% of rural areas to aerial. In reality, placing more underground/buried plant in urban areas is the normal practice due to municipal regulations requiring "out-of-sight" plant. It makes no difference whether the plant is feeder or distribution.

Structure Sharing proposed in HM 3.0 is even more unrealistic than in HM 2.2.2. HM 2.2.2 assumed that 33% of the cost of aerial structure (poles) was assigned to the ILEC. HM 3.0 assumes an even more unrealistic level of sharing. HM 3.0 assumes that 25% of the cost of aerial structure is assigned to the ILEC. In effect, HM 3.0 assumes that a 40 foot pole will have four utilities/carriers attached (Power, CATV, ILEC, and a CLEC). It also assumes that there will always be enough space on the pole to accommodate all four utilities. HM 3.0 assumes that each company will share equally in the cost of the pole. In fact, CATV does not contribute a share of the pole cost equal to power companies and ILECs.

HM 3.0 also applies a portion of interoffice to feeder. Interoffice facilities do not occupy the same feeder structure in every section in every feeder route of a wire center.

Neither HM 2.2.2 nor HM 3.0 indicate a depth of trench. They also do not include a user table for input of a trench depth. However, it is impossible to determine if trench depth is sufficient to allow for sharing of the trench. The trench depth is similar to that in BCM1 (24 inches for copper and 36 inches for fiber) no trench sharing can be assumed because depth and width would have to increase. Cost of trench would also increase.

Structure investments are understated in HM 3.0. In regards to aerial facilities, both versions of Hatfield do not include costs for messengers, guys, and anchors. In addition, pole cost are too low in both versions. In fact, the Hatfield developers have somehow determined that a larger size pole now costs less than a shorter pole. HM 2.2.2 placed a 35 foot pole for $450, and HM 3.0 places a 40 foot pole for a cost of $417. With repsect to conduit, HM 2.2.2. placed only one duet no matter how many cables we placed.

Hatfield manhole investment in the feeder was $3,000. In reality, this amount is about what it would cost for a small handhole (3X5 with a traffic lid) with a capability of two cable placements.

In HM 3.0 the same size manhole is used in all density zones. The investment used ($1,865 for material) indicates that the size of the precast manhole is the 4X8X6 size that will accommodate four ducts. Assuming one duct as spare for maintenance and restoration, that leaves three spaces for cable. High density areas will require more than three cables or 12,600 cable pairs in the feeder. Each 10,000 + CBG will require three full size copper cables (allowing for fill adjustment) to serve it if the CBG is within the copper breakpoint. Therefore manhole assumptions and costs are grossly underestimated. To add to the understatement of cost, Hatfield does not place manholes in the distribution even though the model places conduit there. On page 27 of the documentation, HM 3.0 states that "underground cable is always housed in conduit facilities that extend between manholes or pullboxes." It is typical to place small manholes (pullboxes or handholes) when placing conduit in the distribution. A point at which splicing, pulling, or terminating drop wire is needed. It is also possible that conduit can be terminated in pedestals but there is no indication that pedestal costs were included.[1]

Distribution calculations result in the underestimation of the cost of distribution. First, reduced each quadrant's area uniformly by the percentage of the CBG that is empty. Second, for low density areas, clusters were used to size the distribution grid. Third, HM 3.0 imposed a restriction on the maximum size of lot to be

[1] Note: An error was found in the HM 3.0 model. In the R3_distribution.xls file found in the modules folder, column AP (conduit replacement) looks at density_inputs column 7 (buried cost per foot). There is a significant difference in the cost per foot between these two columns (i.e., density zone 5000 column 6 = $50.10 per foot and column 7 = $13.00 per foot).

three acres or about 361.5 feet by 361.5 feet. The impacts from these two manipulations reduce the amount distribution grid needed. The impact from the third restriction is more complicated. However, the magnitude of that impact may be much greater for lower density area, the type that GTE serves.

Three acres lot per housing unit corresponds to a density of about 214 housing units per square mile. Since the quadrant and clusters are calculated by multiplying the average lot size with that maximum lot size by the number of housing units in the quadrant or cluster, for CO areas with densities less than 214 housing units per square miles, HM 3.0's calculation of distribution grid involved "relocating" the housing units in the areas into the three acre lots located one next to another and then size the distribution grid based on the "newly created Hatfield community" using straight airline miles. As a result, the amount of grid needed is substantially underestimated.[2]

A comparison of total street segment lengths in a selection of 29 California CBGs (provided by Caliper Corp.) to the corresponding HM 3.0 and HM 2.2.2 distribution cable distances shows that there is a substantial change from HM 2.2.2 to HM 3.0 in the amount of distribution loop *without a corresponding change in distribution expense or investment*. It is unclear as to what other change(s) cause the cost counterbalance.

All 29 CBGs are contained entirely within GTE wire centers, and are assigned by both versions of the model to GTE. Street segments which cross over wire center boundaries are excluded. The analysis was restricted due to the enormous data and computational requirements of determining the physical location of streets within CBGs, and to the strict time constraints. See Appendix B for examples.

This exercise compared actual street lengths to the sum of underground, buried & aerial cable columns, and to the "total distribution distance" column, in the "distribution output by CBG" tab of the GTE California default HM 3.0 workfile, as well as to the "Distr Distnc" column in the HM 2.2.2 GTE California default input file.

It is unclear whether HM 3.0 operates on the cable values (e.g., with the "empty fraction") to generate distribution distances to which expense and investment figures are applied, or vice versa. However, where the distribution distances generated by HM 2.2.2 failed to come anywhere close to the corresponding sums of street segment lengths, the observed HM 3.0 distribution distances sum to about 75% of the amount necessary to cover the roads.

Obviously, then, if distribution distance is equivalent to the eventual mileage of cable proposed by HM 3.0, it

[2] The network in the "newly created Hatfield community" may not function. For housing units with densities less than 214 units per square mile, the average shortest distance of the housing unit to the closest distribution branch would have to be at least 180.7 feet (one half of the side length of a 3 acres lot), but the drop in the Hatfield model is limited to 150 feet.

seriously understates the cable needs, AND represents a significant departure from HM 2.2.2 without a commensurate increase in expense and investment. If, however, the HM 3.0 *cable* data is the relevant measure, it may or may not be sufficient in reach, but it represents a *vastly* significant departure from HM 2.2.2 without the commensurate cost increases.

For the 29 observed GTE California CBGs, the total HM 3.0 distribution distance mileage for the 29 CBGs is 351. The total HM 2.2.2 distance is 28. The total lengths of street segments is 470. Preliminary estimates show that the amounts in the HM 3.0 distribution distances range from 4 to 33 times as large as the HM 2.2.2 distances. The sums of the HM 3.0 cable data range from 8 to 108 times as large. On average, the HM 3.0 distances are 17 times larger than in HM 2.2.2, and the cable sums are 36 times larger.

There is some additional evidence of a systematic approach to "correcting" the distribution deficiency by adding cable in such a way as to minimize the resulting cost increases. In general, the larger the size of the observed CBG, the larger the difference between actual street length sums and the observed Hatfield 3 and 222 distribution cable length sums and distances. For HM 3.0, the larger the size of the observed CBG, the percent difference also increases. (For HM 2.2.2, no significant correlation was observed between CBG size and percent difference.)

Distribution cable costs for the default California runs in HM 2.2.2 are $309,954,511. In HM 3.0, despite a total distance of the selected CBGs more than 12 times greater than that in HM 2.2.2, total "cable" over 27 times greater, and a total distance of all CBGs more than 17 times greater, they total $307,511,968. For more information see Appendix F.

HM 3.0 provides some improvement over HM 2.2.2 in how it designs loops, however it still can create loops that will not transmit an acceptable signal. In HM 2.2.2 extremely long loops were engineered but no additional provisioning to account for the problems of long loops took place. In HM 3.0, the attempt to account for long loops falls short in accounting for provisioning cost. The additional cost for loading is understated. Also, the loop lengths assumed to be served from a DLC are too long. A DLC system can not power 178,000 foot loops (a specified lookup value in the Hatfield table), even with the extended range plug-ins. The extended range plug-in can power up to 1500 ohms. The maximum distance that a plug-in can handle is approximately 85,000 feet of copper and that is with an all 19 gauge (16.3 ohms per 1000 ft.) loop including loading (14 load points at 9 ohms each). In reality, copper distribution beyond 85,000 feet (beyond the DLC point) simply won't work.

In HM 2.2.2, the provisioning of extremely long loops used 26 and 24 gauge cables with no loading, gain, or extended range DLC plug-ins. Using these facilities, long distribution loops over 18000 feet would not talk with either an all copper network or a network derived from a DLC. HM 3.0 corrects some of the problems. At least the network may work out to 85,000 on an all copper distribution loop or on an fiber/DLC derived network. However, it will not work out to the limits that have been set by HM 3.0. Additional problems have resulted now that 22 and 19 gauge cables are being used. Those coarse gauge cables do not come in all of sizes that are in the cable tables. For example, the standard cable in 19 gauge ranges in size from 25 - 300. This means that when a 600 pair 19 gauge is required, 2 separate cables plus 2 ducts or 2 spaces on a pole must also be accounted for. None of this has been incorporated in HM 3.0.

Assumptions about cable gauge could not be found in the documentation, but if their assumption is that large size cables (2400 to 4200) are 26 gauge and the remainder are 24 gauge as was in HM 2.2.2, then their cost tables reflect that cost per foot installed. In HM 3.0 they add a multiplier for coarser gauge cable. (The multiplier is not explained fully, except that it is a multiplier of the material cost of the per foot cable investment.) As stated above, 22 and 19 gauge do not come in all cables sizes so that in reality more than one sheath may be required. This will result in HM 3.0 understating cable and structure cost.

The DLC Channel Unit Adjustment table is, first of all mislabeled as Cable Gauge Multiplier, and also very confusing. Apparently DLC plug-ins are increased 25% for loops 55,000 feet to 98,999 feet, no additional cost for plug-ins for loops 99,000 feet to 177,999, and finally plug-in costs are increased again 25% for loops over 178.000 feet. A plug-in adjustment is required for loops exceeding 900 ohms. The adjustment is necessary to increase cost for the placement of extended range plug-ins. The extended range plug-ins increase powering to 1500 ohms. Two major problems exist with the Hatfield HM 3.0 model. One is the cost increase of the extended range plug-in. The increase is more like 2 times the cost of the 900 ohm plug-in. Second problem is the increase doesn't occur until 55,000 feet so the loop won't talk between 50,500 and 55,000 feet. At 55,000 feet there would be 9 points of load (9 ohms per load), assuming an all 19 gauge loop (16.3 ohms per 1000 ft.), the total ohms would be 977.5 ohms.

The terrain multiplier in HM 3.0 has the same flaw as in HM 2.2.2, but it has been compounded by a seemingly contradictory additional multiplier. HM 2.2.2. increase distance by 20% to go around difficult terrain. It even went so far as to decrease trench depth to avoid rock. This was severely disputed. HM 3.0 still applies a 20% increase in distance to go around difficult terrain (which is ridiculous to assume) as HM 2.2.2, but HM 3.0 adds multipliers to account for HARD and SOFT ROCK. This seems to be a contradiction. If difficult terrain is by-passed, then why have a multiplier to increase cost for difficult trenching.

Cable costs in HM 3.0 still appear to be underestimated. The costs of cables remains the same as the same sizes in HM 2.2.2. HM 2.2.2 developed cable costs from four tables used to account for feeder underground, feeder aerial, distribution underground, and distribution aerial cable costs. The problem is that the costs were the same in all tables for the same size cable assuming that there was no difference in labor cost between them. This is a completely false assumption. For example, the cost of laying cable in a trench is a lot less than climbing poles, placing messenger (which none of Hatfield's model account for), and lashing the cable to the messenger. HM 3.0 offers no improvement, because of HM 3.0's false assumption that labor is the same for all types of plant and that the basic cost of material is the same (they apply multipliers for dual sheath and "jelly" filled cable). Due to this assumption, the number of tables can be reduced to two for feeder and distribution with the cost per cable size remaining constant (an additional table is added for riser cables).

The cost for filled cable is not a single cost per foot ($.04 per default table, which is ridiculous anyway) for all types and sizes of cable. For example, the material cost difference between a BKMA-100 air core pic cable and a GFMW -100 filled pic cable is $0.12 per foot. The material cost difference between BKMA-900 air core pic cable and a GFMW-900 filled pic cable is $1.02 per foot.

SAI investment has changed considerably from HM 2.2.2 to HM 3.0. HM 2.2.2 has two tables for SAIs. One for copper feeder and one for fiber feeder. Cost ranged from $500.00 to $2,500 for a copper feeder SAI and $2,500 to $4,500 for a fiber feeder SAI. HM 3.0 costs and tables have changed considerably. Two tables are still used but the types of SAIs have changed. Now they are called "Indoor SAI" and "Outdoor SAI". The documentation still refers to electronics associated with SAIs with fiber feeder but that's as far as it goes. There is no documentation on how costs associated with fiber feeder is incorporated into the table costs. Another big question mark is what is an indoor SAI? The indoor SAI cost must be assuming a building terminal where feeder is cross-connected to house cable. Page 42 of the documentation refers to SAIs in large building as requiring only inexpensive "punch down blocks", thus the cheap costs associated with "Indoor SAIs. This is not entirely true. True, these types of cross-connects do have punch down blocks but they also must include protector blocks that are not inexpensive (190A1-100 installed cost is approximately $572 per block per 100 pair). These protectors are required to stop foreign power from entering buildings and causing fires (among other problems). HM 3.0's method of placing "Indoor SAIs" can result in burning down the businesses it wishes to serve. To include the cost of protection changes HM 3.0s cost for a 100 pair Indoor SAI from $48 to a minimum cost of $620. SAIs associated with fiber/dlc sites are assumed to be housed in the same cabinet (page 41). For "Low Density DLC" sites this may not be a problem but for large ("TR-303 DLC") DLC sites this would be a major problem. There is no cabinet manufactured that will house a 2016 Fiber DLC system plus 3-1200 or 6-600 connecting blocks, a splice chamber that can handle a total of 7200 copper wires, and 144 "710" splice connectors (assuming 1800 working lines @ 89% fill of DLC and 100% fill of SAI). Even if there was a cabinet large enough can you imagine what it might look like to a homeowner looking out his or her picture window. This arrangement of combining a large DLC system with the SAI would be more suitable housed in a hut or a controlled environmental vault (CEV), both of which would add an enormous costs to the facilities. In HM 3.0, current costs range from $250 to $4,469 for "Outdoor SAIs" and $48 to $1,052 for "Indoor SAIs".

DLC investments have improved somewhat, but are still understated. HM 2.2.2's cost are grossly understated. A 672 basic system without plug-ins cost $47,000. The 2.2.2 model apparently did not include some equipment because the cost dramatically increased in HM 3.0. HM 2.2.2 decided that Lucent's TR303 SLC 2000 and AFC' digital loop carrier systems were the systems of choice and that all LECs should model those systems. The maximum size of a DLC system in the HM2.2.2 was 672 and required additional sites when going over that limit. For each additional system another $47,000 was added. However, the DLC cost are still understated.

In HM3.0 a 672 basic system without plug-ins is now $69,000 in HM 3.0. Cost for right of way and DS1 plug-ins appear not to have been included. Other cost such as cabinet cost are grossly understated. To compensate for the additional cost of a 672 system, HM 3.0 adds only $18,000 for additional 672 channels of capacity instead of doubling the costs as in HM 2.2.2. In addition, TR-303 has been misrepresented. TR-303 is currently proprietary to vender specific equipment. For example, only SLC 2000 (Lucent) can talk to a AT&T(Lucent) switch via TR-303. The predominate savings is in the switch and not the DLC equipment. Hatfield is confusing TR-08 with TR-303, both of which are integrated systems.

TR-303 can be actually more expensive than TR-08 or TR-57 (universal) in reality when handing off loop elements to CLECs (especially when demand is low). To hand off from the switch interface uses up a DS1 port in that switch interface that reduces its capacity. This "loopback" increases costs by reducing capacity. The alternative of handing off loop elements at the COT/FOT either as a DS0 or, if demand is high enough, as a DS1 is much more economic. Of course, a switch vendor would prefer a LEC to use up switch ports thus purchasing more switch equipment which is considerably more expensive.

Fill factors have not changed in HM 3.0 with one notable exception. The fill factors are too high and have not changed from HM 2.2.2. However, HM 3.0 now assumes that fiber feeder has a fill factor of 100%. This feeder fill is completely unreasonable, since no network engineer would ever build a network in this manner. To do so would make the network unable to handle short term demand fluctuations caused by competition.

There is no difference between HM 2.2.2 and HM 3.0 in the way cable fills are derived. HM 3.0 claims fills are a MDF fill meaning that the fill is the relationship of the total working lines at the wire center and the total number of pairs (all routes/quadrants combined) terminated on the main distributing frame. Assuming a MDF fill and then applying that fill for sizing of section of plant is incorrect, especially with a fill factor as high as they have set. In reality, the MDF fill is lower than any of the cable sections as an accumulation of all breakage and spare occur here. Typically the further out in a route the higher the fill. To assume a 80% fill at the MDF would be to assume somewhere close to 100% in the last section of a route.

The drop parameters have improved with HM 3.0, however there are still some problems. HM 2.2.2 drop cost per line was a single cost for all density zones and all types of plant. The default cost was $40.00 per drop. In HM 3.0, drop cost is based on an aerial buried mix by density zone, a material cost per foot for both aerial and buried drop, an average length of drop by density zone, and a labor cost per placement (not by foot) for aerial cable in each of the density zones. Two problems occur with this calculation. The default material cost per foot for both types of drop is understated. Examples are, aerial drop cost for density 0-5 is $72.58, density 10,000+ is $16.42, buried drop cost for density 0-5 is $133.50, and density 10,000+ for buried drop is $257.00. Buried drop includes trench. The other problem is drop mix should match distribution cable structure mix. In 0-5 density zone 50% of drops are aerial yet only 25% of structure is aerial.

Terminal and NID Investments are still understated in HM 3.0. Both version's terminal costs per line are not reasonable since only a single cost is applied to all zones. In reality, less dense zones would have a much higher cost per line since sharing of terminal cost would be shared by fewer households. .

In HM 2.2.2 the terminal default cost per line was $32.00 for all types of terminals in all density zones. NID cost was also the same cost ($30.00) in all density zones. The NID was not explained but was universally assumed to be a standard 2 pair NID.

In HM 3.0, terminal cost per line is now based on either a buried terminal cost per line ($42.50) or an aerial terminal cost per line ($32.00) and the mix is based on the Drop Structure Fraction Tables. Page 29 Of the documentation assumes a 2-line NID for residential and a 4-line NID placed for businesses yet a 6-line NID is placed for residential and no size is indicated for businesses. NIDs for single line businesses would typically be the same as NIDs for residential unless the business is located in a multi-business complex. Then another type of arrangement would be typical. Usually it would be an indoor cross-connect where protection would be placed at or near the building entrance (this was discussed earlier when commenting on HM 3.0's assumptions on SAIs). NID cost assumes a 6 line NID which is not standard in a typical 2 line per household network. The way the table is assumed to work is the installed cost of the 6 pair NID is $25.00. Then add $4.00 for protection for every line assumed working in the NID. $29.00 for a single line and decreasing in total cost per line for each additional line. Installing a six line NID not the standard practice for most telecommunications companies. This assumption underestimates NID costs.

HM 3.0 changed the way in which it develops switch costs from HM 2.2.2, however it still underestimates the true cost of switching. The Hatfield Model ("HM") V.2.2.2 relied on three switch cost points and the total number lines in a wire center to determine the switch cost, size and number of switches. It appears HM R.3.0

still relies on three switch cost points[3]. The developers have, however, added a few twists. The basic methodology for determining this investment is to start with one of two precalculated amounts of per line investment[4] for end office switching and remove amounts associated with line related investments, trunk terminations, and digital loop carrier offsets while adding in amounts for STP link terminations and trunk terminations. It is unclear at this point why the STP link terminations were added to the end office switching and why the trunk terminations were first subtracted and then added back. These five items are apparently the only ones considered as contributing to the investment in end office switching. MDF investment is calculated separately but not removed from the end office switching amounts[5]. HM R.3.0 performs what are termed an "additional capacity checks." They are based on Busy Hour Call Attempts ("BHCA") and Busy Hour Hundred Call Seconds ("BHCCS"). The BHCA default maximum in both HM V.2.2.2 and HM R.3.0 is 600,000.[6] BHCA is ostensibly used to determine whether the switch is line limited or processor limited. HM R.3.0's treatment of BHCA differs from HM V.2.2.2 by employing a processor feature loading multiplier to account for the additional processing load associated with vertical features. This variable was included in HM V.2.2.2 but had no effect on the model. HM R.3.0 includes default values that range from 1.2 to 2.0. Both V.2.2.2 and R.3.0 contain two different BHCA input fields for "Switch realtime limit, BHCA", "Busy hour call attempts, residential" and "Busy hour call attempts, business." A decrease in the BHCA capacity should cause an increase in the number of switches and the cost of switching. However, when the stitch real time limit, BHCA was decreased by 20% there was not the expected increase in either the total amount of the end office switching costs or the per minute usage cost. The results were unchanged from the default results. End office switching investment was also unchanged. In fact when the realtime busy hour capacity of the switch was cut 50% there

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[3] The switch cost functions developed by HM3.0 are totally misleading and are based on erroneous statistical analysis. With only three data points, it fitted a log curve using least square technique and found the R square to be more than 96%. But that 96% does not mean anything. They could have done better by using a curve consisting 2 straight line segments going through the three points which would have produced a R square of 100%.

[4] The initial per line investment amounts are dependent upon whether the company involved in the calculation is an RBOC or a large Independent company (in which case the default value is $242.73 per line) or a small Independent company (in which case the default value is $416.11 per line). No documentation has been found for determining the source of these two numbers, at this point.

[5] There is what appears to be an error in the calculation of one of the cells that has an impact on these calculations. The labeling of cell U2 in the Wire Center Investment spreadsheet indicates that it is the total of *only* the direct routed access trunks. However, the calculation adds the value from cell W2 on the same sheet to the end of its calculations. This effectively makes the cell U2 the total of all access trunks (both direct and tandemed). In the first subtraction of trunk terminations in the end office switching calculation, cell W2 is added to cell U2 in an apparent attempt to count all trunk terminations. However, this means that the trunk terminations for tandem routed access have been accounted for twice in this formula. The second instance of trunk terminations in this formula (where the amounts are added back) does not contain the reference to cell W2. The reason for this omission is unknown, although it is missing in most references to total trunk terminations.

[6] This is based on HAI (Hatfield Associates, Inc.) assumptions. See Hatfield Model V.2.2.2 - Input Summary, page 6 of 31.

was no change in switch related costs. The model does exhibit any sensitivity to these real time capacity limits as claimed in the documentation. The input changes are:

Switch real-time limit, BHCA	Default	20% Decrease	50% Decrease	90% Decrease
1-1,000	10,000	8,000	5,000	1,000
1,000-10,000	50,000	40,000	25,000	5,000
10,000-40,000	20,000	160,000	100,000	20,000
40,000 +	600,000	480,000	300,000	60,000

The Results are :

Results for all scenarios except 90% decrease are:

	Annual Cost	Units	Unit Cost
End Office Switching	$22,574,200		
Port	$6,772,260	726,227 Lines	0.78 per line / month
Usage	15,801,940	9,552,246,145 min.	$0.0017 per min.

EO Switching Investment	Total
end office switching	$61,556,956